RECENT ADVANCES IN AGROFORESTRY: SUPPORTING THE TRANSITION FROM CONVENTIONAL TO CLIMATE-RESILIENT FARMING

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Abstract

The significant advances made in agroforestry (AF) during the past four decades make it a prominent strategy for sustainable, Climate Resilient Farming (CRF). Although Europe ranks low in the area under AF (an estimated 20 million ha vs. 1.6 billion ha globally), there has been an emergence (or, re-emergence) of enthusiasm in AF across the continent during the past two decades. In the context of research support for AF as a strategy for CRF, the most prominent areas are carbon (C) sequestration, especially Soil C Sequestration (SCS), and related ecosystem services. Scientific support is crucial for the success of any significant development agenda; it seems doubtful, however, if the science of these crucial ecosystem processes is adequately understood. Learning from the experience of some setbacks that occurred while pushing ambitious AF development agenda in the tropics, it is critical that AF development programs in Europe are backstopped by high-quality research.

Keywords: biodiversity; ecosystem services; meta-analysis; research-based knowledge; soil carbon sequestration

Agroforestry: Increasing Enthusiasm in Europe

After agroforestry debuted on the global land-use scene four decades ago, it used to be characterized for quite some time as “a new name for an old set of practices.” While some historians argue that agroforestry (AF) is as old as agriculture, others quote more recent initiatives and publications to have provided the foundations upon which “modern” agroforestry was built up. No matter when, where, and how agroforestry originated, there is a consensus that the seeds of “modern” agroforestry were sown in 1977 by the international effort that led to the establishment of ICRAF, now the World Agroforestry Centre (www.icraf.cgiar.org). Today, AF is prominently mentioned in most of the common development paradigms and rallying themes. To quote from Nair et al. (2017), these include, in alphabetical order: agroecology, carbon farming, climate-smart agriculture, conservation agriculture, ecoagriculture, evergreen agriculture, multifunctional agriculture, organic agriculture, permaculture, regenerative agriculture, sustainable agriculture, sustainable intensification, and so on. Almost all of them aim at building on the efficient use of locally available resources and integrating different components of the overall production system. Agroforestry systems (AFS) including tree cover on agricultural land are estimated to be practiced over one billion ha of land in the tropics (Zomer et al. 2009), and 1.6 billion ha globally (Nair 2012). Zomer et al. (2016) estimated that the area of agricultural land with at least 10% tree cover – currently 43% of all agricultural land – had increased by 2% over the past 10 years globally.

Europe, in particular, has witnessed a remarkable emergence (or, re-emergence) of enthusiasm in AF during the past two decades; the area under AF in Europe is currently estimated at about 20 million ha (Mosquera-Losada et al. 2012; AGFORWARD 2017). A December 2017 report “*Agroforestry: introducing woody vegetation into specialised crop and livestock systems*” by the EDI-AGRI Focus Group consisting of 20 experts from 15 EU countries noted the growing interest in developing modern, viable agroforestry systems within the EU, and placed emphasis on five examples of AFS that needed pointed attention: the sheep orchard, steep diverse production, chickens under the willows, shaping the landscape, and differentiation in the flatlands.

Climate Resilient Farming

In the scenario of heightened enthusiasm in agroforestry systems (AFS) in Europe (and elsewhere), it is quite appropriate that this conference theme is "Transition from Conventional to Climate Resilient Farming" (CRF). But, what exactly is CRF?

Like sustainability, climate resilience is a much-abused or differently interpreted word and is often understood more by intuition than definition. It is generally understood as the capacity for a socio-ecological system to: (1) absorb stresses and maintain function in the face of external stresses imposed by climate change and (2) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts (Folke 2006; Nelson et al. 2007). As far as the importance of AF as a strategy for CRF and the research in support of that are concerned, the prominent ones are those related to carbon (C), especially Soil C Sequestration (SCS) and other ecosystem services. Indeed, there has been an increasing volume of press and media coverage on the importance of soil health (and C sequestration) vis à vis agroforestry and tree-based farming systems as opportunities for climate-change mitigation and CRF; for example, "*Soil Power! The Dirty Way to a Green Planet*" https://www.nytimes.com/2017/12/02/opinion/sunday/soil-power-the-dirty-way-to-a-green-planet.html New York Times, 02 Dec 2017;

"Can Dirt Save the Earth?" https://mobile.nytimes.com/2018/04/18/magazine/dirt-save-earth-carbon-farming-climate-change.html New York Times, 18 April 2018.

Soil Carbon Sequestration

The fundamental premise is that AFS have a higher potential to sequester C because of their perceived ability for greater capture and utilization of growth resources (light, nutrients, and water) than in single-species crop- or pasture systems. AFS offer greater opportunities than monocultural (single-component) agricultural systems for capture and storage of atmospheric CO_2 in biomass and soils. This has been attributed to several reasons including efficient C (and nutrient) cycling within the soil–plant system, increased return of biomass C to soil, decreased biomass decomposition and soil organic matter (SOM) destabilization in the tropics, and sequestration of soil C in deeper layers of soil (Montagnini and Nair 2004; Nair 2012; Saha et al. 2010)

Although several studies on C sequestration under AFS are reported in the literature, they are highly variable in the study procedures as well as the nature of systems and locations. This makes it difficult to extrapolate the results to broader contexts of systems and locations outside the specific locations of the individual studies. One way of addressing this problem is to undertake a meta-analysis, a statistical procedure for comparing and synthesizing result from different studies for finding common patterns, discrepancies, or other interesting relationships that may not be detectable from individual studies (Borenstein et al. 2009). In a recent meta-analysis that we undertook (Chatterjee et al. unpublished), data were synthesized from 78 peer-reviewed studies that generated 858 data points on SOC stock under various AFS from 25 countries in Asia, Africa, Europe, North America and South America. The data points were used to assess the variations in SOC stocks under AFS in comparison with Agriculture, Forestry, Pasture or Uncultivated Land, in four soil-depth classes (0–20, 0–40, 0–60, and 0–100 cm) in four major agroecological regions (arid and semiarid, ASA; lowland humid tropics, LHT; Mediterranean, MED; and temperate, TEM) around the world. Comparing AFS vs. Agriculture or AFS vs. Pasture, SOC stocks under AFS were higher by +27% in the ASA region, +26% in LHT, and +5.8% in TEM, but –5.3% in the TEM in the 0–100 cm soil depth. Improvement of SOC stocks under AFS varied across agroecological regions, the highest being under lowland humid tropics. Additionally, older agroforests contributed to higher SOC stocks than newly established systems. The results indicated a general pattern of Forest – Agroforest – Agriculture – Pasture continuum in SOC stock decline during land-use changes in all ecological regions.

Biodiversity

Biodiversity is being recognized as one of the best defenses against climate change; protecting it is important for keeping the ecosystems working for us and providing food as well as environmental services (Duffy et al. 2017). The inherently high level of biodiversity of multispecies systems offers several possibilities for arrangement of various tree/shrub/and grass components according to the needs and preferences of farmers. Based on an extensive study in Bangladesh, where the ubiquitous homegardens cover more than 12% of the land area, Webb and Kabir (2009) reported that homegardens provided majority of tree-dominated habitats across the country and therefore represented the only real opportunity to conserve plant and wildlife populations outside of the beleaguered protected-area system. It remains unclear, however, whether few or many of the species in an ecosystem are needed to sustain the provisioning of ecosystem services. Isbell et al. (2011) showed, based on a study of 17 biodiversity experiments, that although species diversity may appear functionally redundant for one set of environmental conditions, many species are needed to maintain multiple functions at multiple times and places in a changing world.

Yet another issue that is being discussed currently is the "C sequestration – Biodiversity connection." Although there is a prevailing pre-conceived notion about positive correlation between C sequestration and species diversity, the relationship between tree C stock and species diversity is not always significant (Richards and Mendez 2014). The existing literature on this relationship is also rather nebulous: both positive and no relationships have been reported. Nevertheless, IPBES (Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services) has recently (March 2018) recognized AF as a biodiversity-promoting activity (https://goo.gl/oJ4DRq).

Research Directions in Agroforestry

Computer modeling and large-scale global estimations are two rapidly progressing procedures in climate change research. Applications of such techniques in agroforestry have, however, been rather limited, which could be a cause or effect of the lack of unanimity of views on the extent to which significant gains can be expected in the immediate future from such efforts in agroforestry. Most of the seemingly reliable crop models are limited to single-species systems where the interaction between plants are restricted to resource utilization among same species (Steduto et al. 2009). The complex nature of arrangement of species within agroforestry systems and the unevenness of plant types and growth habits between different components of AFS (trees, shrubs, herbaceous crops, etc.) hinder progress in their modeling (Luedeling et al. 2014; Bayala et al. 2015). Research-based knowledge on the specific management for each component while grown in combination with other species, and the scope for development of varieties are two important management-related research priorities; these are equally challenging to both modelers and field-oriented researchers (Nair 2017).

The increasing importance being given to largescale computer models and predictions is also noteworthy. Numerous global and country- and regional estimates are available on the potential and magnitude of various ecosystem services; for example, global estimations and predictions on C sequestration (Costanza et al. 2014; Paustian et al. 2016; Kubiszewski et al. 2017). Given the extremely site-specific nature of AFS, studies at the field level should be the starting points for valuing the benefits of their ecosystem services. Furthermore, outputs from AFS are expressions of interactions involving not only easily measurable biophysical factors but also difficult-to-quantify sociocultural factors.

Concluding Comments

Growing enthusiasm in AF is indeed a very welcome trend. We need to be cautious and conscientious, however, about our ability to fulfill the high expectations that are being raised about providing the numerous goods and services. Experience from tropical AF development could be an eye-opener in this context. Enormous levels of enthusiasm and expectations were built up when AF was heralded in the 1980s and 1990s almost as a panacea for land management problems of the tropics, and substantial human and financial resources were expended in fulfilling those aspirations. Soon AF was perceived as an oversold commodity, and it became clear that many land-management advances, especially in the social-political milieu of the tropics, were unrealistic, pie-in-the sky type of illusions. The reality sank in soon after, that the root cause of those setbacks was that the science of AF had not been understood adequately, and consequentially the scientific foundations upon which the euphoria was built up were not strong enough to support the expected quantum leap. We are caught up in a real dilemma: development efforts cannot wait until all the science has been figured out, but if past results are any indication, development efforts involving huge financial outlays and public-relation showcases that are not based on solid principles and foundations are unlikely to be successful.

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